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# WAS THE MAGNETIC WAKE OBSERVED BY "IMP-1" LUNAR OR TERRESTRIAL ?

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## SUMMARY

Comparison of findings by preceding authors and the examination of ground and IMP-1 data, make it difficult to assume that IMP-1 crossed the lunar magnetosphere, whereas the ground data do not exclude the possibility that the magnetic wake of the Earth, directed upward along ths solar plasma flux, would contribute notably to phenomena observed on IMP-1 at sub-Alfvén flow past the Earth's magnetosphere.

Author

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According to contemporary representations, the magnetosphere is formed on the night side of the Earth under the action of such factors as the dynamic and static pressures of solar plasma, the effective viscosity, the pressure of the interplanetary magnetic field and the counterpressure of the geomagnetic field by the magnetosphere plasma and the hydromagnetic radiation [1 – 6]. The cosmic experiments on the night side of the Earth are satisfactorily explained within the framework of these representations [7, 8]. At the same time, these representations are sufficiently general to be utilized for the investigations of the magnetospheres of other planets and in particular of the Moon. One then might also expect that the scales of the lunar magnetosphere are relatively small, for the magnetic moment of the Moon is quite small [9]. In connection with this, the assumption of IMP-1 passage through the lunar magnetosphere is met with difficulties, for it leads to a substantially greater magnetic moment of the Moon than in the direct experiment [9].

* LUNNYY ILI ZEMNOY MAGNITNYY SLED NABLYUDAL IMP-1 ?

According to [10], the extension of the lunar magnetosphere, $\underline{s}$ reaches $150\,R_M$ ($R_M$ being the radius of the Moon), and half of the angle at cone summit is $\alpha \sim 11^o$. If we admitted that the entire magnetic field flux is carried beyond the surface of the Moon into the "tail" of the magnetosphere by the solar wind, the lower limit of the magnetic moment of the Moon, $M_M$ is by its order of magnitude to $R_M H(s\, tg\, \alpha)^2$, which at field intensity $\sim 10\gamma$ in the lunar "train" would be leading to $M_M \gtrsim 4 \cdot 10^{23}$ CGSM. The estimate of the upper limit of $M_M$ [9] should be corrected for the effect of solar wind [12]. However, this correction is equal to only 30%, since the concentration of protons and the velocity lf the wind during the period of measurement were respectively $n \sim 10 cm^{-3}$, $v = 500\, km/sec$ [13], that is, $M_M \leqslant 10^{21}$ CGSM. This value of $M_M$ does not rule out the possibility of IMP-1 passage through the region behind the shock wave front and through the magnetohydrodynamic wake of the Moon [10, 11]. However, one must be very careful when referring to this possibility, for two subsequent attempts to detect the wake of the Moon had led to negative results [11].

Besides, one may assume that the observed phenomena were caused by perturbation spreading from the Sun, or represented the magnetohydrodynamic wake of the Earth, directed upward along the solar plasma flux. It is well that sub-Alfvén flow of viscous fluid $v < v_A = H/(4\,nm)^{1/2}$ there forms a wake of a solid directed upward along the flow of the incident plasma [14]. It may be assumed that there exists in space, at separate periods, a sub-Alfvén flow of the solar wind, and that the perturbations, generated by the effective viscosity at magnetosphere boundary [15], form a magnetohydrodynamic trace of the Earth, spreading upward along the solar wind flow. The formation of such a wake could have taken place also during the period of observations on IMP-1 of anomalous events in space. There was no possibility of verifying this assumption, for the data on plasma have not been published as yet. However, a series of data do corroborate the possibility of such an interpretation. Thus, during the period of these observations, the magnetic field was somewhat above the average value, equal to $4-7\ \gamma$ [10], and reached during one of the periods $14.6\ \gamma$, which, at other equal conditions, might have increased $v_A$ by 2 to 4 times, and thus facilitate the transfer from super-Alfvén to sub-Alfvén flow.

It should be noted that in December 1963 other events were observed in space, having criteria inherent to events at sub-Alfvén flow. On 20 December, the fast shock wave ahead of the magnetosphere was absent [10, Fig. 21], which could have taken place at sub-Alfvén flow past the Earth's magnetosphere. At that time the field in the space was $9 - 12\ \gamma$. On 2 December a sudden commencement was observed, which had either formed at passage of a tangential break, or of a complex break, constituting a combination of a slow shock wave with a rotary break. A similar break is formed at sub-Alfvén flow [14].

Comparison of the magnetograms for 14 — 15 December, obtained on IMP-1 and by ground stations, points to the similarity of IMP-1 and a series of high-latitude observatory readings.

To perturbations in space corresponded perturbations on Earth, with at the same time the field in space being most perturbed in the periods of stronger disturbances on Earth (for example, the bay between 12 00 and 16 00 hours U.T. on 14 December), and even registration gaps occurred on the IMP-1 magnetograms [11]. The most striking pulse on the IMP-1 registration ( near 01 00 hours UT on 15 December) was also noted by a series of high-latitude observatories (Fig. 1). In this figure $|\bar{F}|$ is the total vector of the magnetic field, $Y_{SE}$ is the component of the interplanetary field in the dextro-helical solar-ecliptical system of coordinates, whose axes $\underline{x}$ and $\underline{y}$ are respectively directed at the Sun and toward the southern ecliptic pole; X, Y, Z, H, D are the components of the Earth's magnetic field.

In order to verify the assumption of sud-Alfvén flow of the solar wind during this period, we measured the onset time of this pulse on Earth and in space. Had the pulse been the initial pulse of Earth's wake directed upward along the flow, that is the pulse, occurring at magnetosphere boundary, it should have been observed on Earth 2 to 3 minutes earlier than in space, at distance of 30 R from the Earth's center, for the path time of the hydromagnetic wave from the magnetosphere boundary to the Earth's surface is $\sim 1$ minute [16], and to IMP-1, at sub-Alfvén flow and $v \sim 500 - 700$ km/sec it is near 3 to 4 minutes. To the contrary, if this pulse had arrived on Earth from a distance of 30 R at daytime side of the Earth, its onset in space should have been observed 3 to 4 minutes earlier than on Earth. Observation data point to the fact that this pulse was apparently observed on the Earth's surface somewhat earlier than in space. Compiled in Table 1 are the results of determination of the onset of this pulse from magnetograms of six ground observatories and of IMP-1 ($t_o$).

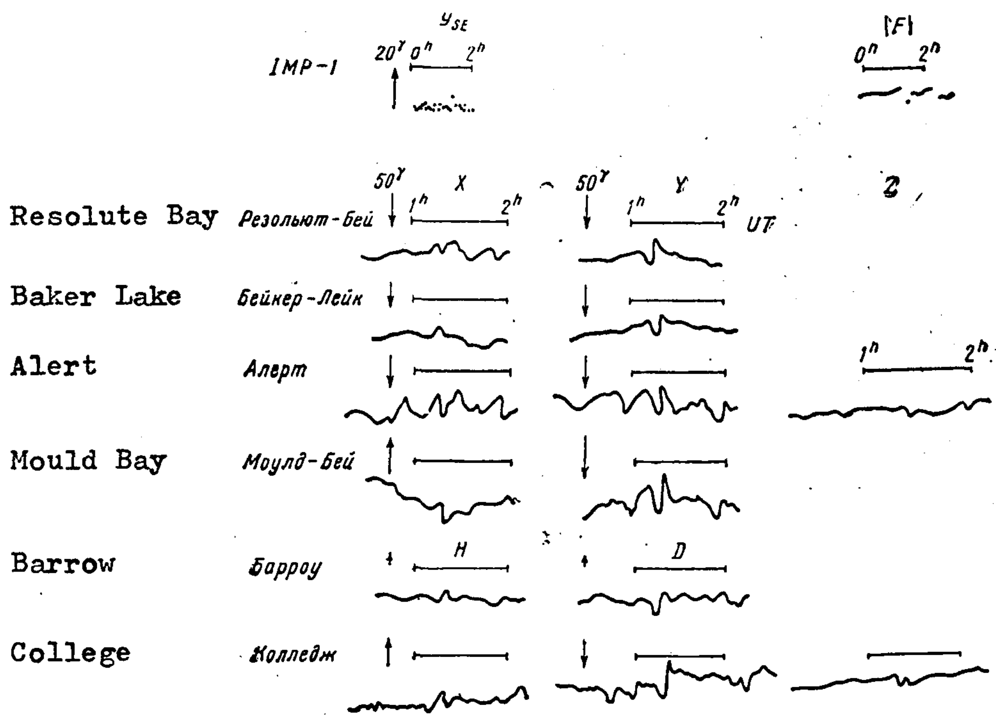


Fig. 1

The pulse began on the ground at 01 14½ ± ½ min. The data of IMP-1, brought out in [11], do not allow to determine accurately the onset time of the pulse in space, for they are plotted according to the mean values for intervals of 5.46 min. duration. However, it is obvious that the pulse either began at the beginning of the 15th interval, after 00 00 hours UT on 15 Dec., or at the very end of the 14th interval, that is, between 01 15 and 01 20 hours UT, whereas at its propagation from the distance of 30 R, the pulse onset on IMP-1 registration would correspond to the end of the 13th interval.

Therefore, ground data do not exclude the possibility that the magnetic wake of the Earth, directed upward along the flux of solar plasma, at sub-Alfvén flow past the Earth's magnetosphere, contributed notably to events observed on IMP-1.

see Table 1 ../..

TABLE 1

| Observatory | IMP- 1 | Resolute -Bay | | Baker Lake | Alert | | Mould Bay | | Barrow | | College | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Element | $Y_{SE}$ | X | Y | Y | X | Y | X | Y | H | D | H | D |
| $t_0$, U.T. | 0115 — 0120 | 14.5 | 14 | 15 | 14 | 14.5 | 14 | 14.5 | 14.5 | 13.5 | 14 | 14.5 |

In conclusion, I extend my thanks to Yu. D. Kalinin for stating the problem, discussing the work, and to E. I. Mogilevskiy for his valuable remarks.

*** THE END ***

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REFERENCES

[1].- D.Kh. PIDDINGTON.- Sb. "Solnechnyye korpuskulyarnyye potoki i ikh vzaimodeystviye s magnitnym polem Zemli". (Solar corpuscular streams and their interaction with the Earth's magnetic field). IL., 383, 1962.

[2].- W. I. AXFORD, C. O. HINES.- Canad.J. Phys., 39, 1433, 1961.

[3].- E H. PIDDINGTON.- Plan. Space Sci., 9, 305, 1962.

[4].- J. R. SPREITER, B. J. HYETT.- J. Geophys. Res., 68, 1631, 1963.

[5].- L. LEES.- AIAA J., 2, 1576, 1964

[6].- A. J. DESSLER.- J.Geophys. Res. 69, 3913, 1964.

[7].- J. P. HEPPNER, N. F. NESS, C. S. SCEARCE, T. L. SKILLMAN - Ib. 68, 1, 1963

[8].- A. BONETTI, H. S. BRIDGE, A. J. LAZARUS et al.- Ib., 68, 4017, 1963

[9].- Sh. Sh. DOLGINOV, E. G. YEROSHENKO, L. N. ZHUZGOV, N. V. PUSHKOV.- Geomagn. i Aeronom., 1, 1, 21, 1961.

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References continued

[10].- N. F. NESS, C. S. SCEARCE, J. B. SEEK., J.Geophys. Res. 69, 3531, 1964.

[11].- N. F. NESS.- Magnetohydrodynamic wake of the Moon.- Preprint 1964.

[12].- M. NEUGEBAUER.- Phys.Rev.Lett. 4, 6, 1960.

[13].- E. R. HARRISON.- J. Geophys.Astron.Soc., 6, 479, 1962.

[14].- A. G. KULIKOVSKIY , G. A. LYUBIMOV.- Magnitnaya gidrodinamika. (Magentohydrodynamics).- Fizmatgiz, 1962

[15].- W. I. AXFORD.- Plan.Space Sci. 12, 45, 1964.

[16].- W. E. FRANCIS, M. I. GREEN, A. J. DESSLER.- J.Geophys.Res. 64,1646, 1959.

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